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How face mask usage duration and type affect tear break-up time (TBUT): A survey of health professionals at Sanglah Hospital Denpasar

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ABSTRACT

Background: As society adapts to the new normal during the Corona Virus Disease 2019 (COVID-19) pandemic, face masks have become one of the health protocols required in the community, especially among health professionals. Wearing a mask regularly for an extended period may lead to dry eye symptoms, which cause discomfort and affect the quality of life. This study aimed to determine the association between the face mask usage duration and type with tear break-up time (TBUT) reduction among health professionals at Sanglah Hospital Denpasar.
Methods: This cross-sectional analytic study was conducted from December 2021 to January 2022. A simple cluster random sampling method was used to obtain 107 health professionals who wore face masks, aged 21-55 years old, and were qualified for both the inclusion and exclusion criteria. The data were collected using a questionnaire and a TBUT test. A chi-square test and multiple logistic regression analysis were performed to determine the association. The $p<0.05$ was significant.
Results: TBUT reduction was experienced by 30 subjects (29%) after wearing face masks, with an average of about 6±4 seconds. The duration of mask usage ≥6.5 hours per day significantly increased the risk of TBUT reduction by 2.708 times higher than the duration <6.5 hours per day (AOR 2.708; 95% CI 1.099-6.673; p=0.027). Using a non-N95 mask increased the risk of TBUT reduction by 4.545 times higher than the N95 mask (AOR 4.545, 95%CI 0.556-37.135; p=0.125).
Conclusion: There was an association between face mask usage duration and type with TBUT reduction.

Keywords: Dry Eyes, Face Mask, MADE, TBUT, Health Professionals.
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INTRODUCTION

An outbreak of novel pneumonia caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), known as Coronavirus Disease 2019 (COVID-19), occurred in Wuhan, Hubei, China. COVID-19 spread rapidly worldwide and was declared a pandemic in March 2020. The prevalence of confirmed COVID-19 cases in Indonesia had reached 1 million cases at the end of January 2021.[1] Due to the rapid transmission of COVID-19 through droplets and aerosols transmission, mask usage became a must in the community, especially for health professionals. Previous studies stated that using a mask regularly for an extended duration could increase the evaporation rate of tear films, which resulted in irritation of the ocular surface, causing dry eye syndrome known as mask-associated dry eye (MADE).[2–5]

A survey by Boccardo et al. showed that 658 participants (26.9%) reported worsening dry eye symptoms when using the mask, and 18.3% of participants were diagnosed with MADE.[6] Moshirfar et al. also stated that mask usage contributes to the increased prevalence of dry eye in patients and health professionals in the hospital.[5] In addition, Marinova et al. found that the type and duration of mask usage ≥6 hours per day may increase the risk for dry eye disease, leading to eye discomfort, itchy feeling, blurry vision, foreign body sensation, and redness in the eye.[7]

Dry eye is a multifactorial disease of the ocular surface characterized by loss of tear film homeostasis that causes inflammation and damage to the ocular surface. Dry eye conditions significantly decrease the patient's quality of life and productivity.[8] The increase in the MADE incidence during the COVID-19 pandemic will immensely affect health professionals who are obligated to wear masks regularly for a longer time. Unfortunately, detailed explanations regarding the association between mask use and dry eye incidence remain very limited. To our knowledge, there are no studies regarding MADE in Indonesia. This study determined the association between the face mask usage duration and type with tear break-up time (TBUT) among health professionals.

MATERIAL AND METHODS

Study design and subjects

This prospective analytic cross-sectional study involved 107 health professionals who wear masks regularly during work at Sanglah Hospital Denpasar from December 2021 until January 2022. Ethical considerations for the study has been approved by The Ethics Committee of Universitas Udayana with Ethical Clearance number of 2718/UN14.2.2.VII.14/LT/2021. All subjects in this study had signed the informed consent form before participating.

All subjects involved in this study were 21-55 years old. Participants who were pregnant, had reached menopause, had external eye disease or systemic disease that might affect the tear film, wearing goggles or taped mask, on topical eye drops, used contact lenses in the last one week, had a history of eye surgery in the past six months, or post-chemotherapy were excluded from this study. Eligible subjects were chosen from 15 different wards in the hospital randomly using simple cluster random sampling.

Data Collecting

All participants were provided a questionnaire before the first TBUT measurement to obtain their demographic and habit data, including age, sex, history, mask type, work environment, and gadget time. The first TBUT (TBUT I) was measured before the start of their work shift. The test was performed by rubbing a fluorescent strip on the inferior fornix of the eye. This study utilized strips manufactured by Surgitech Innovation. Then the tear film was examined using a portable slit lamp with cobalt-blue illumination and 10x magnification. The first dark spot that appeared from the last blinking was recorded using a timer in seconds, and the result was rounded up if it exceeded 50 per hundredth of a second. The examination was carried out three times in a row, and then the average was taken and rounded to the nearest whole number. A normal TBUT value must be at least 10 seconds. If it were less than 10 seconds, the TBUT would be considered abnormal. The second TBUT (TBUT II) was performed after the subjects finished their work shift, and the time between TBUT I and TBUT II were calculated as the duration of mask usage. The TBUT reduction cut-off was determined based on previous studies.[9,10] TBUT reduction means that there is a difference between the values of TBUT I and TBUT II, which is >6 seconds if the value of TBUT I is normal and >3.5 seconds if the value of TBUT I is abnormal. By the end of the study, all participants were given artificial tears sponsored by Cendo.

Statistical analysis

All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) software, and univariate analysis was done on all variables. Categorical data were presented in frequency and percentages. Numeric data with normal distribution were presented using mean ± standard deviation (SD), while numeric data not normally distributed were presented as the median and interquartile range (IQR). The duration of mask usage was transformed into a dichotomous variable using a cut-off obtained from receiver operating characteristic (ROC) analysis. The association between face mask usage duration and type with TBUT reduction was assessed using a chi-square test. A multiple logistic regression analysis was performed to determine the risk of TBUT reduction after controlling the confounding variables. Any result with a p-value less than 0.05 was considered statistically significant.

RESULTS

This study involved 107 health professionals at Sanglah Hospital Denpasar. Most participants were female (68.2%) and aged under 40 (83.2%). The non-N95 mask (89.7%) was the most common mask type used, in which most subjects did not wear a double mask (64.5%). Most participants worked in air-conditioned (AC) rooms (86%) and had a habit of using gadgets for more than 2 hours per day (82.2%). Table 1 showed that most subjects had normal TBUT I and TBUT II values (94.4% and 72.9%, respectively). The mean results of TBUT I and II were 17±5 and 11±4 seconds, respectively. Thirty-one subjects (29%) had a decrease in TBUT after using a mask with an overall mean TBUT reduction of 6±4 seconds.

Table 2 showed that the mean duration of mask used in the population was 6±2 hours. Furthermore, we divided the mask usage duration based on the cut-off from ROC analysis which was 6.5 hours (Figure 1). This cut-off had a sensitivity of 39.4%, specificity of 78.4%, and area under the curve (AUC) of 0.572. Bivariate analysis using a chi-square test showed that wearing a mask for ≥6.5 hours significantly increased the risk of TBUT reduction by 2.708 times higher (OR 2.708; 95%CI 1.099-6.673, p=0.027). Wearing a non-N95 mask was also found to increase the risk of TBUT reduction by 4.545 times higher, but this result was not statistically significant (OR 4.545; 95%CI 0.556-37,135; p=0.125).

A multivariate analysis was performed to determine the association between face mask usage duration and type with TBUT reduction after controlling the confounding factors, such as age, sex, gadget use, double mask, AC room, TBUT I, and mask type. The result of multiple logistic regression (Table 4) showed that duration of mask usage ≥ 6.5 was the only significant risk factor for decreasing TBUT value in this study (AOR 2.708; 95%CI 1.099-6.673, p = 0.030).

DISCUSSION

Dry eye syndrome is a multifactorial disease caused by instability and hyperosmolarity of the tear films resulting in inflammation and damaged ocular surface. TBUT is an objective test used to assess the stability of the tear film, which is widely used for diagnosing dry eye syndrome (DES). This study's mean TBUT value before mask usage (TBUT I) was 17±5 seconds, consistent with a study that involved 100 health professionals in India that found a mean TBUT value of 13.84±1.84 seconds.[11]

DES has a variety of different etiology and pathogenesis. Hence its risk factors also vary, ranging from physiological, pathological, and environmental risk factors. Physiological risk factors include age and menopause in women. This study found no significant association between age and TBUT reduction. Similarly, Krolo et al. showed no association between dry eye symptoms based on OSDI score and age groups (<40, 40-60, dan >60 years).[12]

On the other hand, Yuliastini et al. found that lower TBUT values are significantly associated with older age (>60 years old).[13] Aging and menopause are associated with decreased lacrimal and meibomian glands function. Thus the tear film tends to become unstable.[14] The result of this study revealed no association between age and TBUT reduction because this study's design excluded subjects over 55 years old.

Environmental factors, such as room air humidity, are also risk factors for dry eye. Cold airflow can affect the lipid layer. Studies show that the meibomian lipid layer has a melting point between 32.5-35°C. If the temperature drops below that range, the lipid production by the meibomian will also decrease. Therefore the evaporation rate of the tear film will increase. Rooms with AC will increase the risk of dry eye by disrupting the stability of the tear film due to constant exposure to cold air.[15] The results of this study indicated that working in rooms with AC was a risk factor for a decrease in TBUT value, but it was not statistically significant. The temperature of the room where the subject worked in this study was not accurately measured. In contrast, the ability of the air conditioner to lower the air temperature in each room was different. Hence, this result cannot support the previous study's theory.

Bista et al. suggested that the increased use of gadgets caused the increased incidence of dry eye during the pandemic because almost all work, teaching, and learning activities are carried out online using electronic devices.[16] The study by Inomata et al. showed that exposure to screen gadgets for more than 8 hours per day was significantly associated with dry eye symptoms ($p<0.001$). The results of this study also provided a similar situation where prolonged use of gadgets had a risk of lowering TBUT, but it was not statistically significant. This outcome may happen due to recall bias when data collection was conducted based on a self-reported questionnaire and not through objective measurements of screen time for each subject.[17]

Another result found in this study was a risk of TBUT reduction in subjects who did not wear a double mask and had an abnormal TBUT I at the start of the examination, yet both were not statistically significant. The relationship between these results was not confirmed since no comparative study existed. However, it is estimated that the results were insignificant because the distribution of the sample was uneven in the two groups, where the percentage of subjects wearing double masks and abnormal TBUT I was still limited.

The use of masks has now become a new habit since the COVID-19 pandemic. Masks are often used for a longer time, especially by health professionals. This mask usage is believed to increase the incidence of the so-called mask-associated

Table 1. Subject's characteristics.

Characteristics	Frequency (N)	Percentage (%)
Sex		
Male	34	31.8
Female	73	68.2
Age		
< 40 y.o	89	83.2
≥ 40 y.o	18	16.8
Mask type		
Non-N95 mask	96	89.7
N95 mask	11	10.3
Double mask		
Yes	38	35.5
No	69	64.5
AC room		
Yes	92	86.0
No	15	14.0
Gadget use		
≤ 2 hours	19	17.8
> 2 hours	88	82.2
TBUT I		
Normal	101	94.4
Abnormal	6	5.6
TBUT II		
Normal	78	72.9
Abnormal	29	27.1
ΔTBUT		
Decreased	31	29.0
Stable	76	71.0
Total	**107**	**100**

Notes:
Abbreviations: AC: Air-Conditioner; TBUT: Tear Break-up Time; ΔTBUT: value difference between TBUT I and TBUT II.

Table 2. Characteristics of TBUT and mask duration.

Variables	Mean±SD	Minimum	Maximum
TBUT I (seconds)	17±5	9	35
TBUT II (seconds)	11±4	5	22
Δ TBUT (seconds)	6±4	1	24
Mask duration (hours)	6±2	4	15

Notes:
Abbreviations: SD: Standard Deviation; TBUT: Tear Break-up Time; ΔTBUT: value difference between TBUT I and TBUT II.

dry eye (MADE). Several case study studies show that many patients complain of worsening dry eye symptoms when using a mask. A study by Krolo et al. related the duration of wearing a mask with the incidence of dry eye, which was assessed using the OSDI score. This study reports that those who use face masks for 3-6 hours per day have significantly lower OSDI values than those who wear masks for less than 3 hours.[12]

Scalinci et al. conducted a study regarding the association between the duration of wearing a mask and OSDI score. The respective research showed that wearing a mask > 6 hours per day for five days a week increased the OSDI score ($p<0.001$). This increase in OSDI indicates worsening dry eye symptoms, suggesting a worse tear film. The increase in OSDI, related to the duration of wearing this mask, is also indirectly associated with a decrease in TBUT.[18] This was proven by Yazdani et al., who found that the OSDI score had a significant negative correlation with the TBUT value ($r=-0.091$, $p<0.0001$).[19] Anwar et al. also showed that a longer duration of mask wears caused tear film instability, decreased tear volume, and increased OSDI scores. A significantly lower TBUT value was found in the mask users with a duration of use > 2 hours per day ($p<0.05$). Anwar et al. also found a moderate negative linear correlation between the TBUT value and the duration of wearing a mask ($r=-0.427$). Similar results were found in this study, even after controlling for confounding factors (AOR 2.708; 95% CI 1.099-6.673; $p=0.030$).[11]

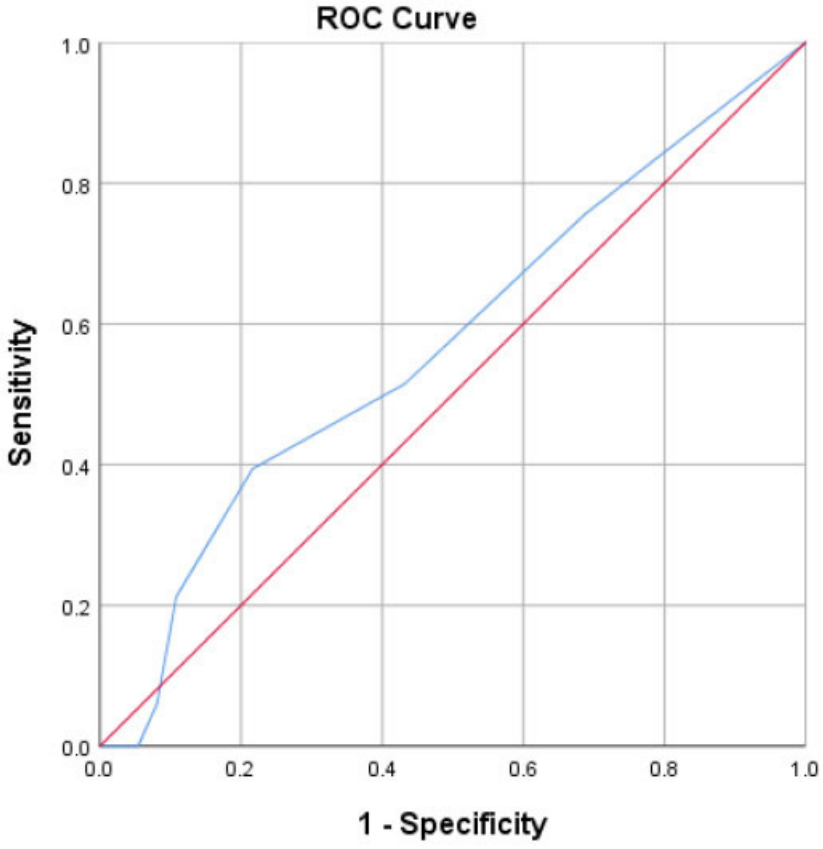

Figure 1. Receiver operating curve (ROC) analysis result of mask duration in detecting TBUT reduction.

Mask-associated dry eye is predicted to occur, especially during mask wear that is not tight enough, causing air to flow out from the gap at the top of the mask. The outgoing airflow is the warmer exhaled air, generally contributing to 11% of the total body heat loss.[18] Exposure to warm air accelerates tear evaporation, resulting in hyperosmolarity and tear film instability.[11,20] Exposure to CO2 from exhaled air may also cause a decrease in tear pH and increase the formation of free radicals that trigger hypoxia, inflammatory reactions, and changes in tear film instability.[11,21] Based on this theory, we can conclude that the longer the use of the mask, the longer the exposure to air will also be on the tear film, resulting in an increased risk of tear film instability, which is indicated by a decrease in TBUT according to the results in this study.

The type of mask used based on the density level can also affect the instability of the tear film. Masks, such as the N95 type, are indeed designed to fit the wearer's face, which can prevent the exhaled air from escaping from the top of the mask. This theory is supported by previous studies, which found that using N95 masks and protective eyewear can reduce the incidence of dry eye in health professionals.[3] This study is the first to assess the relationship between mask type and tear film instability using TBUT measurements. This study's results indicated a relationship between the use

Table 3. Comparison of TBUT reduction by usage duration and mask type.

Variables	Decreased TBUT	Stable TBUT	p-value	OR	95%CI
Mask duration					
≥ 6.5 hours	13 (44.8)	16 (55.2)	0.027*	2.708	1.099-6.673
< 6.5 hours	18 (23.1)	60 (76.9)			
Mask type					
Non-N95 mask	30 (31.3)	66 (68.8)	0.125	4.545	0.556-37.135
N95 mask	1 (9.1)	10 (90.9)			

Notes: *Chi-square test, p-value < 0.05 is considered significant.
Abbreviations: 95%CI: 95% Confidence Interval; OR: Odds Ratio; TBUT: Tear Break-up Time.

Table 4. Analysis result of TBUT reduction using multiple logistic regression.

Variables	First Step			Final Step		
	p-value	AOR	95% CI	p-value	AOR	95% CI
Mask duration	0.099	2.287	0.855-6.118	0.030*	2.708	1.099-6.673
Mask type	0.176	4.429	0.513-38.226	-	-	-
Gadget use	0.122	4152	0.685-25.172	-	-	-
Double mask	0.414	1.517	0.558-4.124	-	-	-
Age	0.508	0.619	0.149-2.563	-	-	-
AC room	0.556	0.630	0.135-2.936	-	-	-
Sex	0.785	1.141	0.442-2.943	-	-	-
TBUT I	0.893	1.138	0.173-7.477	-	-	-

Notes: *Chi-square test, p-value < 0.05 is considered significant.
Abbreviations: AC, Air-Conditioner; AOR, Adjusted Odds Ratio; 95%CI, 95% Confidence Interval; TBUT, Tear Break-up Time; TBUT I, Tear Break-up Time at the beginning of mask usage.

of non-N95 masks in increasing the risk of TBUT reduction by 4.545 times higher than that of N95 masks. Thus it could be considered clinically important (OR 4.545; 95% CI 0.556-37.135; p = 0.125). The authors are not yet able to conclude whether tight masks can reduce the risk of TBUT reduction due to the imbalanced number of samples between the two types of masks (1:8.7). This results in a high variation in sample calculations, making it difficult to achieve the statistical significance of the study.

Mask usage is associated with a decrease in TBUT, an increase in OSDI values, and a higher incidence of dry eye. However, masks are undoubtedly mandatory to prevent and protect oneself from COVID-19 infection in this pandemic era. Several studies suggest using protective eyewear to maintain humidity in the air around the eyes while wearing a mask.[3,7,16] Tomlinson et al. suggested using eye drops, especially those containing sodium carmellose and lipid formulas simultaneously, to reduce tear evaporation.[22]

This research is an analytical study using a cross-sectional method, which has several limitations that could potentially lead to biased outcomes, including the absence of a control group with a history of not wearing a mask, high variance with an unbalanced comparison of the number of samples between groups, the absence of only one examiner measuring TBUT, the lack of detailed data on how each type of mask affects the airflow coming out of the upper gap of the masks, as well as the possibility of a chronic condition in the tear film due to the process of the MADE mechanism, considering that regular use of masks has been mandatory since early 2020.

This research is the first pilot study in Indonesia that studied the association between face mask usage duration and type with TBUT reduction. Several previous studies have attempted to link the length of mask usage with dry eye using the OSDI value. In contrast, this study used a more objective measuring instrument for the TBUT reduction from each subject before and after using the mask. The researcher calculated the duration of wearing a mask directly by evaluating the time interval between the two TBUT examinations, not based on the results of the subject's memory, thereby reducing recall bias. This study involved various confounding factors known as the risk factors for dry eye and conducted a multivariate analysis to control for these factors. The results of this study are expected to be a valuable contribution to future studies related to the use of masks and the incidence of dry eye.

CONCLUSION

Health professionals using face masks for an extended duration and a loose-fit type were predicted to experience an increased risk of TBUT reduction, thus increasing the risk for dry eye syndrome. However, wearing a face mask is mandatory and has more significant benefits in preventing COVID-19 transmission during the pandemic. Wearing protective goggles, a mask with tape on the top, and lubricating eye drops may help minimize the risk of dry eye syndrome in this population.

DISCLOSURE

Conflict of Interest

The author reports no conflicts of interest in this work. No funding was given for this research, the sponsor was provided for the respondent's incentive.

Authors Contribution

The authors confirm their contribution to the paper as follows: study conception and design: Andy William, Wayan Eka Sutyawan; data collection: Andy William; analysis and interpretation of results: Andy William; draft manuscript preparation: Andy William; Andy William, Wayan Eka Sutyawan, I Gusti Ayu, Made Juliari, I Gde Raka Widiana, Ni Kompyang Rahayu, and I Made Agus Kusumadjaja reviewed the results and approved the final version of the manuscript.

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